

# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

### Improvements in Multi-Stage Compressors with Intercooling

- We, SOCIETE RATEAU, a French Body Corporate, of 40, rue du Colisee, Paris, Seine, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to multi-stage compressors with interstage cooling.
- It is customary at present to arrange the intercoolers associated with multi-stage centrifugal compressors in the compressor body itself or, at least, in casings fixed directly to the compressor body.
- However, the progress which has been achieved in aerodynamics and in mechanics has resulted in a reduction of the dimensions of the moving parts of such compressors while simultaneously increasing the rotational speeds thereof, so that they are of relatively low cost and yet have high performance. As the dimensions of the intercoolers are not correspondingly reduced, the accommodation thereof in the body of the compressor has become more and more difficult. The connecting ducts, which are of complicated form, complicate manufacture and their changes of direction and of section are prejudicial to the overall compressor efficiency, especially at the low pressure or inlet end of a compressor, where the occurrence of separation effects is most to be feared.
- Among multi-stage compressors with interstage cooling, this invention relates to centrifugal compressors of the kind (referred to hereinafter as "the kind referred to") which have a casing which supports an externally mounted interstage cooler or coolers; such compressors comprise an inlet duct for the supply of fluid to the compressor, an outlet duct for the delivery of fluid from the compressor and intermediate ducts for the transfer of fluid to and from the interstage cooler or coolers, the said ducts being distributed along the axial length of the compressor. The invention has for its principal object to provide an arrangement of the stages of a compressor of the kind referred to, which enables the said cooler or, if there is more than one cooler, at least the cooler situated at the low pressure end of the compressor, to be turned round and to be provided with very direct connecting ducts without, in spite of this, increasing the length of the moving parts.
- In the conventional arrangement of a multi-stage centrifugal compression, all the stages are traversed (by the fluid) in the same axial direction. The inlet and outlet ducts of the compressor, regarded as a whole, are arranged at the end of the assembly of all the ducts and they frame all the intermediate ducts connected to the interstage coolers.
- It has already been proposed, in centrifugal compressors having built-in interstage coolers, to dispose the diffusers of the final and penultimate stages adjacent one another in the axial direction. However, it is more difficult to turn round any stage other than the final one, by reason of the small radii of curvature which need be adopted for the intermediate ducts.
- According to the invention, however, there is provided a multi-stage centrifugal compressor of the kind referred to, wherein the low pressure or inlet stage, at least, is reversed, in such manner that the duct located at the end of the assembly of ducts which is nearer the end of the compressor at which the said inlet stage is located is an intermediate duct.
- Apart from enabling the above-mentioned object to be achieved, a further advantage of the arrangement according to the invention resides in the reduction of the axial thrust of the moving assembly of the stages,

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which arises from turning round at least one stage, and in some cases this enables the conventional axial balancing piston to be dispensed with. The description which follows with reference to the accompanying drawings, which is given by way of non-limitative example, will make the various features of the invention and the manner in which they are carried into effect clearly understood.

In the drawings:—

Figure 1 shows in axial section a conventional six-stage centrifugal compressor provided with three intercoolers arranged between stages 1 and 2, 2 and 3, 4 and 5, respectively, and

Figure 2 shows in a similar view an equivalent compressor in accordance with the invention.

Referring to Figure 1 there is shown therein a multi-stage compressor, the rotors of the six stages of which, numbered respectively from 1 to 6, are carried by a shaft 7. The latter, driven at the end 8, is mounted in two bearings 9 and 10 and axially located by a stop or abutment 11. Seals, such as the labyrinth packing 12, are disposed between the stages and at the ends of the shaft.

It is to be noted that since the rotors are all arranged in the same axial direction, the axial thrusts thereon are cumulative and must be balanced by a piston 13. The piston 13 has a face 14 which is subject to the delivery pressure, while the opposite face 15 is subject to a selected lower pressure.

The inlet ducts of the several stages respectively bear the references 1a, 2a . . . . 6a, and the corresponding delivery ducts the reference 1r, 2r . . . . 6r. It is obvious that the ducts 1a and 6r are not in the same plane as the others.

The positions of the intercoolers are represented schematically by the arrows 16<sub>1</sub>, 16<sub>2</sub> and 16<sub>3</sub>. They are arranged between stages 1 and 2, stages 2 and 3, and stages 4 and 5, but could be provided between other stages if thermodynamic requirements made this necessary. It is to be observed that the lateral dimensions of the coolers require a sinuous form of the ducts 1r, 4r and 5a, and this entails two main drawbacks:

- pressure losses in the curved ducts,
- difficulties in manufacturing the corresponding parts.

Figure 2 relates to an equivalent compressor, but constructed in accordance with the invention. The same reference designate corresponding parts in the two figures.

The rotors 2, 3 and 4 have a normal arrangement substantially identical to that already described. The rotor 1 is turned round or reversed, as is the assembly of rotors 5 and 6 and the corresponding diffusers.

The inlet duct 1a and the delivery duct 6r are framed by the ducts 1r and 5a, respectively, located at the two ends of the compressor. The result is that the coolers 16<sub>1</sub> and 16<sub>3</sub> can easily be arranged in line with said ends without it being necessary to impose a considerable curvature on the intermediate ducts, as can be seen by comparing the two figures of the drawings.

Moreover, it is acceptable, as shown, to provide a greater curvature for the high-pressure ducts 4r and 5a, where separation effects are less to be feared.

The method of construction in accordance with the invention therefore reduces the pressure losses and facilitates the construction of the diaphragms and of the compressor stator or frame. Moreover, the axial thrusts of the reversed rotors 1, 5 and 6 balance, or very nearly balance, those of the normally directed rotors 2, 3 and 4. It is thus possible to dispense with the axial balancing piston.

It is obvious that the invention is not limited to the construction form thus described, but that it also covers those which it is possible to obtain by employing equivalent technical means.

In particular, a series of reversed rotors may comprise any number of such rotors.

#### WHAT WE CLAIM IS:—

1. A multistage centrifugal compressor of the kind referred to, wherein the low pressure or inlet stage, at least, is reversed, in such manner that the duct located at the end of the assembly of ducts which is nearer the end of the compressor at which the said inlet stage is located is an intermediate duct.
2. A compressor according to claim 1, wherein at least two compression stages and the associated connecting duct or ducts are reversed together.
3. A multi-stage compressor constructed and arranged substantially as herein particularly described with reference to Figure 2 of the accompanying drawings.

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 This drawing is a reproduction of  
 the Original on a reduced scale.

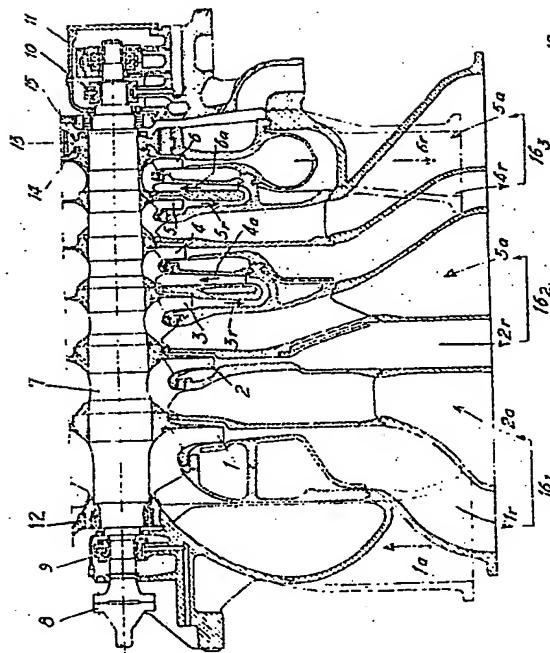


Fig. 1

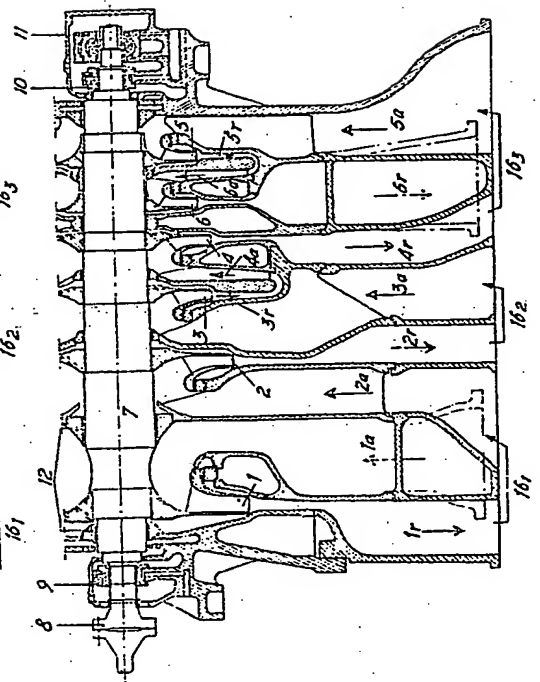


Fig. 2